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MINUTES AND PROCEEDINGS

of the eighth meeting of the

ARMY - NAVY - OSRD VISION COMMITTEE

12 December 1944

National Academy of Sciences
Washington, D. C.



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U.S. Armed Forces-NRC Vision Committee

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# ARMY - NAVY - OSRD VISION COMMITTEE

## MINUTES

Ninth Meeting
National Academy of Sciences
Washington, D. C.
1000, 12 December 1944

The following were present:

| | | |
|---|---|---|
| ARMY | AAF | (M)Dr. D. W. Bronk |
| | | (A)Major Paul Fitts |
| | | (A)Lt. A. Chapanis |
| | | Dr. R. B. Loucks, School of Aviation Medicine, Randolph Field |
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| | AGO | (M)Dr. Edwin R. Henry |
| | Ord | (A)Mr. John E. Darr |
| | | Mr. William Grant, Research and Development Division |
| | QMG | (A)Capt. R. M. Toucey |
| | | Mr. Philip von Lubken, Research and Development Branch |
| | Sig | Dr. George P. Horton, Operational Research Staff |
| | SG | (A)Major M. E. Randolph |
| | | Major L. B. Roberts, Armored Medical Research Laboratory |
| | WDLO | (M)Capt. Howard E. Clements |
| | BuAer | (M)Comdr. Lester Wolfe |
| | | (A)Lt. Harry London |
| | | (CM)Lt. Comdr. David F. Leavitt |
| | | Ens. Marjorie C. Bronson, Instruments Branch |
| | | Ens. F. G. Hagadorn, Lighting Section, R & E Branch |
| | | Lt. Lewis R. Hardy, Jr., Instruments Branch |
| | | Mr. John M. Roper, Electrical Section. |
| | | Lt. (jg) V. Withington, Instruments Branch |
| | | Lt. Comdr. T. D. Davies, Engineering Division |
| | BuMed | (A)Lt. Comdr. R. H. Peckham |
| | | Lt. John A. Bromer, Franklin Institute, Philadelphia |
| | | Lt. Harry J. Older, Aviation Psychology Section |
| | BuOrd | (A)Lt. (jg) Nathan H. Pulling |
| | | Ens. Kenneth V. Knight, Research and Development Division |
| | | Lt. Comdr. N. J. Smith, Research and Development Division |
| | BuShips | (A)Lt. C. G. Hamaker |
| | | Lt. Comdr. R. E. Brown, Camouflage Section |
| | | Lt. Comdr. R. M. Langer, Physics Research Section |
| | I C Bd | Mr. Allen E. Swim |
| | NMRI | (CM)Dr. Harold F. Blum |
| | | Lt. Comdr. R. H. Lee |
| | NRL | (M)Dr. E. O. Hulburt |
| | | (A)Dr. Richard Tousey |

| | | |
|---|---|---|
| NAS | | Lt. Jesse Orlansky, Dispensary, Naval Air Station, Quonset P |
| SCNRD | (M) | Lt. Comdr. H. G. Dyke |
| SubBase | (M) | Capt. C. W. Shilling |
| | (A) | Lt. (jg) W. S. Verplanck |
| ATC | | Lt. C. W. DeWitt, Amphibious Training Command, Norfolk |
| | | Lt. John Sulzman, Amphibious Training Command, Norfolk |
| DCNO (Air) | | Lt. W. C. Schaefer, Gunnery Training Section |
| NDRC | (M) | Dr. Brian O'Brien |
| | (CM) | Dr. F. E. Wright |
| | | Dr. S. Q. Duntley, Section 16.3, M.I.T. |
| APP | (M) | Dr. Charles W. Bray |
| | (M) | Dr. H. K. Hartline |
| CMR | (M) | Dr. Walter Miles |
| | | Dr. Hamilton Southworth, London, Representative |
| NRC | (CM) | Dr. Selig Hecht |
| OSRD | (M) | Dr. Donald G. Marquis |

W/Cdr. Percey A. Lee, RAF Delegation
Mr. Alan L. Morse, Civil Aeronautics Administration
Mr. Walter C. Newcomb, University of Rochester
W.Cdr. J.V.V. Nicholls, Royal Canadian Air Force, Ottawa
Mr. Harry S. Purnell, Jr., Civil Aeronautics Administration
Surg. Comdr. D. Y. Solandt, RCN Medical Research Unit, Banting Institute
Mr. H. W. Vaughan, British Air Commission

1. The chairman called for corrections or alterations in the Minutes and Proceedings of the seventh meeting. The following corrections should be made: On pg. 16, line 10, "red" should read "rod"; on pg. 26, line 16, "9 to 90 foot lamberts" should read "$9 \times 10^{-6}$ to $90 \times 10^{-6}$ foot lamberts."
   On pg. 21, Minutes and Proceedings, fifth meeting, the retinal intensity of XN30 lens should read 15.6% instead of 5.6%.
   In the report "Shipboard Study of Performance of Night Lookouts" by W.C.H. Prentice (Proceedings, sixth meeting, pp. 26-27) an error in the treatment of the data was discovered by Dr. Duntley. Correction does not change any of the conclusions, but does alter some of the absolute values involved. The corrections have been incorporated in the final project report now available, A Study of the Performance of Night Lookouts Aboard Ship, OSRD Report No. 4087, 15 October 1944, 36pp.

2. Lt. Comdr. R. H. Peckham described and demonstrated various types of sun-scanning goggles, and discussed the present status of sun-scanning equipment research. 9

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ARMY - NAVY - OSRD VISION COMMITTEE

PROCEEDINGS

Ninth Meeting
National Academy of Sciences
Washington, D. C.
1000, 12 December 1944

2. PRESENT STATUS OF SUN-SCANNING EQUIPMENT RESEARCH

The following report was prepared and presented by Lt. Comdr. R. H. Peckham.

The preliminary phases of research on sun-scanning equipment have been completed. The amounts of absorption for adequate protection have been determined; methods of production and availability of material have been examined as far as possible until definite recommendations have been forwarded by the Vision Committee, the Bureau of Aeronautics, the Bureau of Ships, and the various testing boards of the Army. When a satisfactory design for sun-scanning has been approved, the problems of production will then have to be met. The BuMed has undertaken the development of three types of sun-scanning equipment:

(a) Equipment in which the whole field is darkened.

(b) Equipment in which identical portions of both eyes are covered by identical areas.

(c) Equipment which uses the fusion density principle first described by Dr. Walter Miles.

Of the three general principles, the principle (a) has met with the greatest field acceptance, but it is the opinion of the writer that this is the least satisfactory from the viewpoint of probability of detecting aircraft near the sun. Equipment of the type (b) requires interpupillary adjustment, and after initial trials it was decided to use this type only in binoculars where adequate interpupillary adjustment is already available. Equipment of the third type (c) has been tried in various Navy projects, and details with regard to the transmissions of the various parts have been resolved. (Spot .02%, Visor 30%, Lens 30%).

Examples of these various attempts were available for examination at the meeting, and a very brilliant lamp source was provided for viewing. The following samples were presented:

Sample #1. Variable-density goggles with a tracer filter and fusion-density spots. These have been reported as worthy of use by the Army Anti-aircraft Board. There is at present some discussion as to the size of the spots (see Dr. Miles' report, p. 16). These goggles do not satisfactorily absorb solar energy in the region between 700 and 2300 millimicrons. A report at the sixth meeting of the Vision Committee indicated the necessity for and choice of a glass to accomplish the required absorption in this band of infrared radiation, and the Army specifications have been re-written to cover this point. The Navy plans to procure some of this type of equipment without the tracer shield, and the necessary infrared protection will be included.

Sample #2 shows the application of the variable-density principle to binoculars. Considerable difficulty has been found in the matching of the two oculars for density with these tiny filters when they are turned to maximum absorption. It was necessary to visit the manufacturer's plant in Chicago. The writer, with the aid of a representative of BuShips, was able to devise an assembling and testing procedure which would permit no greater difference between the two sides than 1 log unit. While this seems to be a considerable amount, a compromise between physiological desirability, manufacturing tolerances, and practical effect in the field has to be reached. As manufactured before inspection, the difference between the two eyes was as great as two log units. Examples of these differences were tried in looking at brilliant sources of light, and it was found that even such a large difference did not interfere with the instrument in use provided that the lighter of the two sides was itself of sufficient density. Examination of a larger group of filters taken from the assembly line before inspection showed that about 25% of the devices were manufactured with an error less than .3 log units and that 3/4 of the manufactured material could be expected to be of less than 1 log unit difference. All of the filters were found, by virtue of a heat absorbing glass which has been included, to show sufficient absorption of solar energy to be satisfactory according to the recommendations of this Committee. At present, the manufacturer of these filters has conceded to the specification of 1 log unit difference and has set up salvage methods to replace those filters showing a difference greater than this amount. These devices are being procured by the Army, the Navy, and the Marine Corps. They may be attached to any pair of binoculars and permit the examination of the solar disc.

Sample #3. is a device as yet in the experimental stage which consists of a pair of binoculars in which occluding areas are formed by evaporating aluminum on the field lens in the eye pieces. This device was delivered but recently, and no field tests have been made as yet.

PRESENT STATUS OF SUN SCANNERS

| Type Description | Origin | Manufactured By | Field Test | Recommended | In Issue |
|---|---|---|---|---|---|
| VARIABLE DENSITY | | | | | |
| Var-Dens. (A) | ——— | American Optical Co. | ——— | ——— | Army, Navy, British |
| Var-Dens. (B) | BuMed | American Optical Co. | None needed | Vision Committee | No |
| Var-Dens. (C) | Army | American Optical Co. | Army Anti-aircraft Bd. | ——— | |
| V-D Binoc. | ——— | Beck-Lee Corp. | ——— | BuMed | Army, Navy Marines |
| OCCLUDING SPOTS-FUSION CONTOUR | | | | | |
| Plastic Visor | BuMed | Polaroid Corp. | No | Rejected BuMed | No |
| Var-Dens. Spots | Vision Committee | Polaroid Corp. | BuMed | Rejected BuMed | |
| Glass Spots | Australia | | BuShips | Rejected BuShips | Australia |
| OCCLUDING SPOTS-FUSION DENSITY (MILES) | | | | | |
| Glass and Gelatine Horiz. and Vertical | Yale (Dr. Miles) | ——— | BuShips | Rejected BuShips | No |
| Glass and Gelatine Diag. | Yale (Dr. Miles) | ——— | Not yet | ——— | ——— |
| Plastic visor M1944 Aviat. Goggle | BuMed | Polaroid Corp. | BuShips BuAer | Recommended for further development BuShips | No |

PRESENT STATUS OF SUN SCANNERS (continued)

| Type Description | Origin | Manufactured By | Field Test | Recommended | In Issue |
|---|---|---|---|---|---|
| GRADED DENSITY | | | | | |
| Glass | Zeiss Shooting Glass | Germany | No | No | ——— |
| Glass and Metal | Univ. of Rochester (Dr. O'Brien) | Bausch & Lomb | Army Air Forces | ——— | No |
| Plastic | Army Air Forces | Polaroid Corp. | Not yet | ——— | ——— |
| Tracer Glass & Gelatine | Royal Can. Navy | ——— | RCN | RCN | Planned |
| MECHANICAL DEVICES | | | | | |
| Elastic Hollow Window with Opaque Fluid | BuAer Special Devices | ——— | No | Rejected BuAer | No |
| Icaruscope | Univ. of Rochester (Dr. O'Brien) | Universal Camera Corp. | ——— | Recommended BuShips | Planned |

Further information on any item is requested from members of the Army-Navy-OSRD Vision Committee.

Sample #4 is one of a series of sun-scanning devices made of plastic and containing the fusion-density principle. Various combinations of brightnesses for the various lenses, each arranged to yield the necessary absorption, were tried in field tests conducted at Patuxent, Maryland. As a result of these tests, it was recommended that the sample shown to the Committee be procured. At the same time, BuShips made field tests of similar samples and recommended that the visor attachment be made as large as the whole opening of the goggle and of the same lobar shape. To date, no decision has been reached on this point, and BuShips is procuring a limited number with large visors for further field trials.

In summary, samples have been designed, examples of these have been forwarded to operating Bureaus for trial, but, at present, the operating Bureaus have not completed their field tests. Each of the devices described, with the exception of the fixed spots in the binoculars, has received both complimentary and condemning reports. It was suggested that the samples exhibited to the Committee be examined by the various members and that if any members find their departments interested in further development, they communicate with the writer, who will make samples available.

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Discussion:

Dr. O'Brien pointed out that the graded-density goggle mentioned by Lt. Comdr. Peckham is the same form of goggle the AAF wishes to subject to extensive field tests. It is good for conditions of viewing sand and snow or when flying over overcast. The lens and color have been modified for the AAF tests. The AAF prefer the color of Rose-Smoke to the gray-green of Calobar or Rayban. Rose-Smoke is nearly neutral but has a strong blue-violet absorption. It is thought that haze penetration is improved by cutting off the short end of the spectrum. The center of the goggle at present has a density of .45 (transmission about 40%). The RAF favors a transmission of 25-30% for sunglasses, while we prefer transmissions of around 15%. The next batch of Rose-Smoke will be .7-.8 density, or about 15% transmission. The present density of the top of the goggles is from 3.0 to 3.1. If the density of the center were modified from .45 to .75, the density at the top would become 3.4, which would be better for viewing the sun. More experience through service tests is necessary to determine the optimum densities for the goggles.

Lt. Comdr. Peckham called attention to the fact that adaptation to the change in brightness when using sunglasses takes place rapidly and that some studies indicate that adaptation also takes place to color — green becomes almost neutral. Some losses of color perception occur, however, when adaptation to brightness and color is required at the same time. Therefore, any color

in sunglass lenses is undesirable. An examination of Rose-Smoke indicates that when visual brightness of Rose-Smoke, Rayban, and Calobar is the same, Rose-Smoke has one and one-half the saturation of Rayban and one and one-quarter the saturation of Calobar. At 15% transmission the saturation for all three lenses is high, greater than two Munsell units of saturation. At 5% (equivalent to polarizing lenses) saturation is extremely high and low saturation colors are lost. Lt. Comdr. Peckham again emphasized the importance of striving towards neutral lenses, but the minimum requirements should be no more than 2 Munsell Units of saturation. The Polaroid development of the graded-density goggles for the AAF has been retarded as a result of the difficulty in procuring dye for a reasonably neutral plastic lens.

Several members were interested in the most desirable color for sunglass lenses. Dr. O'Brien thought that, although no scientific evidence justifies it, the unsaturated green of Rayban or Calobar is the most desirable color. There seems to be a strong preference for it among users. Dr. Hecht, indicating that yellow should theoretically be the best color, asked how the choice of any given lens had been made -- by comparing two possibilities or as a result of a trial of a series of colors. Lt. Comdr. Peckham said that the choice of Rose-Smoke (a yellow lens) over green was made by comparing the two colors.

Dr. O'Brien said that when the popular green sunglasses were developed, the choice was between green and what was then known as smoke. He suggested that a psychologist might have an answer for the common preference for green. Lt. Comdr. Peckham offered the explanation that the green automatically takes out the extreme wavelengths; therefore, it was easy to sell to the public through high-powered advertising as a protective glass. They were obtainable at higher prices, the accepted sign of quality.

Dr. Hartline reported that the origin of preference for Rose-Smoke in the AAF was a statement by someone in the Arctic who claimed that it made shadows more distinct. Dr. Duntley suggested that the preference for Rose-Smoke may be a result of better visibility rather than color difference. Evidence from studies with the Spectrogeograph, which measures the spectral quality of radiation reaching an observer flying in a plane, show that the space from air to ground contributes more blue light than any other. The contrast of all natural objects is reduced since, in the lower end of the spectrum, contrast is very slight.

Lt. Farnsworth's current study on the effect of various colored glasses on threshold differences for hues was noted.

Lt. Verplanck called attention to the fact that sun-scanning is called for under a variety of different conditions, and that the goggles and devices should be designed with respect to the particular job in which they will be used. There is no one type of device to satisfy all requirements. For example, it has been established that anti-aircraft lookouts should scan with binoculars. In that case what possible use are goggles? Development of sun-scanning binoculars and other magnifying sights should be pushed in place of goggles. Different devices can be evaluated only by careful measurement of spotting efficiency under field conditions.

## 3. SIZE AND ORIENTATION OF THE OBSCURING AREA IN FUSION-DENSITY GOGGLES FOR SUN SCANNING

In response to request from the Office of the Quartermaster General the following report was prepared and presented by Dr. Walter Miles.

In the early stages of developing the fusion-density goggles for sun scanning, preliminary trials showed there was no particular advantage in making the filter strips, or sun-scanning spots, wider than 8 mm. when mounted 35 to 40 mm. from the observor's eyes. This width of 8 mm. was chosen as suitable for making field tests. Factors taken into consideration in this choice were as follows: (1) It is necessary to have the diameter of the fusion square greater than the diameter of the pupil. (2) It is desirable to have the square large enough so that observors find it readily in distinction to the rest of the projected figure. (3) There is need to demonstrate the fusion square to officers and others indoors when the pupils are dilated and there is no opportunity to try out the device against the sun. (4) The area of the fusion square produced by 8 mm. strips is sufficiently large so that unskilled lookouts can place it over the sun by a quick head movement, or by observing the shadow of the patch through the closed eyelids. Direct flash of the sun through the surrounding lens of the goggles is minimized by a large obscuring area, especially in early trials.

Now that field tests have been made, and the fusion-density principle appears to be applicable to sun scanning under military conditions, the optimal dimensions of the obscuring area should be reviewed. Enemy planes may appear directly in line with the sun or in the area near the sun. Therefore, the disc of the sun and the surrounding area need to be scrutinized with a minimum loss of time through transferring the observor's fixation and attention from one area to another. The ideal obscuring area would be one that precisely covered the disc of the sun and was independent of eye and head movements. For monocular observation this ideal could perhaps be approximately achieved by placing an obscuring area at some considerable distance from the observer and requiring him to move appropriately to keep the sun and the obscuring area in line. There are many conditions under which this would be a clumsy and unworkable arrangement. The fusion-density goggles undertake to give a convenient, workable binocular solution for the sun-scanning problem but do not achieve a perfect solution. The obscuring area reveals the sun's disc wherever it may be placed within that area. The most effective routine seems to be to place the sun near the border of the area, for example, in one corner. When this is done, the observer is blinded from seeing a plane that may be anywhere within the sky space covered by the remainder of the obscuring patch. This blind area should be as small

as possible, at the same time sufficiently large to keep the sun covered in spite of necessary small eye movements.

The problem of the optimal obscuring area may be taken up theoretically, but at present it seems that empirical data based on out-of-door observations would better serve our immediate purpose. Six pairs of goggles (Willson Type X32), all identical except for patch width, were made up and tried out in observations on the sun and on suitable targets arranged to be viewed against the sky when the sun was shining. The patch widths in these six experimental goggles were carefully made, varying in steps of 1 mm., from an over-all patch width of 3 mm. to 8 mm. In the type of mounting employed the sun-scanning spots were 35 to 40 mm. from the observer's eyes and approximately tangent to the line of regard. They were made of neutral density, 3.00, Wratten No. 96 gelatin filters sandwiched between glass welders' lenses, shade No. 5, and white thin cover glasses. The rated density of the fusion patch for use on the sun was 4.71 (Proceedings, second meeting, p. 11).

The targets against which the patch sizes were measured subjectively in terms of degrees of visual angle were set up on the parapet of a roof, tangent to the position of the observer, who was 114.5 ft. distant. The targets were vertical metal rods 3/8 in. in diameter placed at intervals of 1 ft. so as to provide 16 gaps or spaces, each closely approximating $\frac{1}{2}^{o}$ of visual angle as subtended at the corneas of the observer. The subject was seated on a lower roof and looked up $10^{o}$ from the horizontal. He rested his elbows on a high stool to provide head support and endeavored to ascertain the width of coverage of the fusion square as seen against the line of vertical target spaces.

In making the tests the goggles were tried in progressive order and also in random order. A subject would adjust the position of the fusion patch by head movement until it just obscured the upper portion of one terminal post. Then he counted the gaps bracketed by the square. With the larger squares it was sometimes more convenient to count the number of gaps left uncovered. In both methods there is an error due to changing fixation points, but the method is probably sufficiently accurate for our purpose.

The summarized results for five subjects are as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| Patch width in mm. | 8 | 7 | 6 | 5 | 4 | 3 |
| Fusion square coverage in degrees | 4.5-6.5 | 2.0-4.7 | 1.5-4.5 | 1.3-3.0 | 1.0-2.0 | ? |

It was found that 3 mm. was too narrow to provide a fusion-density square suitable for observation on the sun. Patch widths from 4 to 8 mm. inclusive all gave workable obscuring areas for the sun's disc. The larger values for each patch width corresponded with the conditions when direct sunlight was strongest on the observer's face.

The goggles with 4 mm. strips gave an obscuring square which, projected, measured 1-2° in diameter; 5 mm. goggles gave squares 2-3° in diameter. The results for the 4 and 5 mm. strip goggles could be verified in observations made on the sun, using the sun's diameter as $\frac{1}{2}$°. The diameter found for the 6 mm. goggles ranged from $2\frac{1}{2}$-4°. For the 7 mm. goggles the results in plotted curves are slightly irregular, showing from 3 3/4-$4\frac{1}{2}$°. This may result from changing to the method of counting the spaces left uncovered. Finally, for the 8 mm. goggles, the diameter is $4\frac{1}{2}$-6°, which equals 9 to 12 times the sun's diameter.

When the patches were extended farther from the observer's eyes by an amount of 20 mm. by placing a vacant goggle frame over the subject's eyes under the goggles carrying the filters, the projected square was reduced about 1° for each of goggles 5, 6, 7, and 8. Observations made under ordinary artificial illumination, with consequently more dilated pupils, gave in each case patch diameters less than those found on the rooftop. The decrease was in general about $1\frac{1}{2}$° for goggles with 6, 7, and 8 mm. patch widths.

The angular size of the fusion square as seen projected in the sky obviously depends on (1) the width of the strips carried in the goggles, (2) the distance from the subject's eyes to the strips, and (3) the diameter of the pupils. The latter value is influenced inversely by sky brightness. The fusion square itself is an umbra about 4° in diameter. This seems adequate for scanning the sun and for protecting the pupils from direct rays through the lenses when fixating areas of sky near the sun. But this protection in large part depends on appropriate head movements which shift the sun toward the center of the square as the observer shifts his fixations away from the sun.

These results must be regarded as preliminary. They need checking by field tests and especially by observations from moving platforms.

## Orientation of Obscuring Square

The fusion-density goggles thus far distributed for trial, or made up by others, have, I believe, employed only horizontal and vertical strips. The projected figure takes the form of a cross with the long axis horizontal, and usually the cross is not symmetrical. An alternate arrangement is to place the strips in diagonal positions. The projected figure in the sky then has the form of an X,

and the diagonal of the fusion square is vertical. Many seem to prefer this arrangement, as it gives direct views laterally and vertically away from the sun. If the strips are so placed as to form a V in the goggles, that is, with the top ends more widely separated than the bottom ends, then the fusion square for far vision occupies a higher position in the visual field than when nearer fixation is used. This arrangement promotes comfort in looking upward. The diagonal orientation of the obscuring square seems worthy of consideration before any extensive production of sun-scanning goggles employing the fusion-density principle is initiated.

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Discussion:

Dr. Bray offered to make available to anyone interested in testing sungoggles an observational set-up including a moving platform and targets for observation.

Lt. Comdr. Brown stated that in his experience the blinding glare exists not only in viewing targets against the sun's disc, but also against the surrounding sky. The halation diminishes gradually with distance from the sun until sufficient contrast is present for visibility of the target. He thought that the design of any sun-scanning goggle should pay special attention to the viewing of targets near rather than on the sun, and asked if any data are available which indicate where the area of high contrast begins for various kinds of atmospheric conditions.

Lt. Comdr. Peckham pointed out that the area immediately surrounding the sun on a very clear day would have a brightness of about 250 foot candles. On a day with high haze, the same area may be as high as 100,000 foot candles. The problem in devising sun-scanning goggles is to have an instrument that can be used in any situation. The protection of the sun-scanning spot has to be effective for an area of $1^{\circ}$ to $2^{\circ}$ on either side of the sun to distances as great as $10^{\circ}$. When the density of the protective spot is adequate for protection against the brightest sun, it is too dense for seeing the sun's disc on a hazy day. Any one instrument will be imperfect for all conditions, but a compromise instrument is more useful than one perfect for a single condition.

Dr. Miles stressed the importance of Lt. Comdr. Brown's question. If it is comfortable to look at the sun, observation is possible around the sun. He pointed out that one weakness of the variable-density goggles with sun-obscuring spots is that the relative obscuring area is placed nearer the eye than the near point. The edge of the patch cannot be seen clearly. Diffraction rings exist, and viewing is faulty in the area $\frac{1}{2}^{\circ}$ to $1^{\circ}$ off the obscuring area.

## 4. SUN-SCANNING TRACER GOGGLES

The following report is an abridgement of Sun-Scanning Tracer Goggles: Report on Goggles Designed to Permit Sky-Scanning in the Vicinity of the Sun and Facilitate the Observation of Tracer Bullets under These Conditions, submitted by Lt. M. L. Bunker and Surg. Comdr. D. Y. Solandt to the Royal Canadian Navy Medical Research Unit.

Goggles designed to facilitate the observation of tracer bullets fired towards the unoccluded sun must satisfy four major requirements. They must attenuate the visible light reaching the eyes of the gunner sufficiently to prevent excessive discomfort when the image of the sun is focussed on the foveal region of the retina. The ultraviolet and infrared light reaching the eyes must also be specifically reduced to prevent conjunctival and retinal damage. In the experiments to be described, filter combinations which satisfy these requisites and exhibit maximum transmissions at wavelengths corresponding to the prominent lines in the tracer spectrum were investigated.

Evaluated on the basis of these four properties, the most satisfactory filters tried were combinations of 5 mm. of Corning Signal Green No. 4407 (1) with one thickness of either a Wratten No. 31 gelatin filter or a Wratten No. 33 gelatin filter. These filter combinations were assembled by cementing the Wratten filter between two layers (each 2.5 mm. thick) of the Corning filter. The cement used was the new Bausch and Lomb product (CPD-11) which withstands extremes of temperature and was found to harden in a very satisfactory manner when left standing at room temperature.

### Density

The densities of the filter combination used were determined as follows:

(a) Spectral analysis method as described in the Handbook of Colorimetry (2).

(b) Photoelectric method using General Electric Light Sensitive Cell PJ22 with 4 mm. Corning Glass Filter #300 and 1 mm. of Corning Glass Filter #429 to simulate approximately the visibility curve of the human eye.

| Filter Combination | Transmission of Visible Light Method (a) | Method (b) |
|---|---|---|
| 1. CG4407 + W31 | 1.11% | 1.11% |
| 2. CG4407 + W33 | 0.25% | 0.26% |

In practice these two filter combinations were found to reduce the amount of visible light reaching the eyes directly from the ball of the sun to a bearable intensity and preserve sufficient illumination to permit effective scanning of the sky in the region adjacent to the sun.

Peckham (3) has laid down standards for goggle density on the basis of a goggle providing a small region of high density for the occlusion of the sun. In our trials gunners found it quite impractical to make effective use of such occluding patches. The filter combinations listed above have been designed to offer a compromise in density which would not necessitate the use of regions of extra density.

## Ultraviolet Attenuation

The ultraviolet transmission was measured using a Hilger Spekker Spectrophotometer (Department of Physics, University of Toronto) under the direction of Professor H. J. C. Ireton. Both filter combinations absorb all radiation with wavelengths shorter than 370 millimicrons, and, thus, meet Admiralty specifications (4) for protection from ultraviolet radiation and those laid down by Peckham (3).

## Infrared Attenuation

Transmission curves between 350 and 750 millimicrons were plotted, using a Cenco-Sheard Spectrophotometer (Department of Physiology, University of Toronto), as shown in Figure I.

The infrared transmission was measured with a Hilger Infrared Spectrophotometer with rock salt prism (Department of Physics, University of Toronto). Readings were also taken when 24 mm. of water (to simulate ocular media) were placed in front of the filter. No transmission could be observed in this case.

Effective solar transmission was determined by Peckham's (5) method with the following results:

| Filter Combination | Total Energy | Retinal Intensity |
|---|---|---|
| 1. CG4407 + W31 | 9.1% | 1.8% |
| 2. CG4407 + W33 | 6.9% | 0.9% |

Blum (6) has proposed a spectral curve of solar energy reaching the retina. By this method, the following results were obtained:

| Filter Combination | Transmission of Solar Energy to Retina |
|---|---|
| 1. CG4407 + W31 | 3.4% |
| 2. CG4407 + W33 | 2.3% |

Admiralty specifications (4) for heat protection are as follows:

(a) Transmission of filter to visible light 1-20%, transmission of filter to heat when combined with 24 mm. of water to be not greater than twice the transmission to visible light.

(b) Transmission of filter to visible light less than 1%, transmission of the filter to heat, when combined with 24 mm. of water to be not greater than 1%.

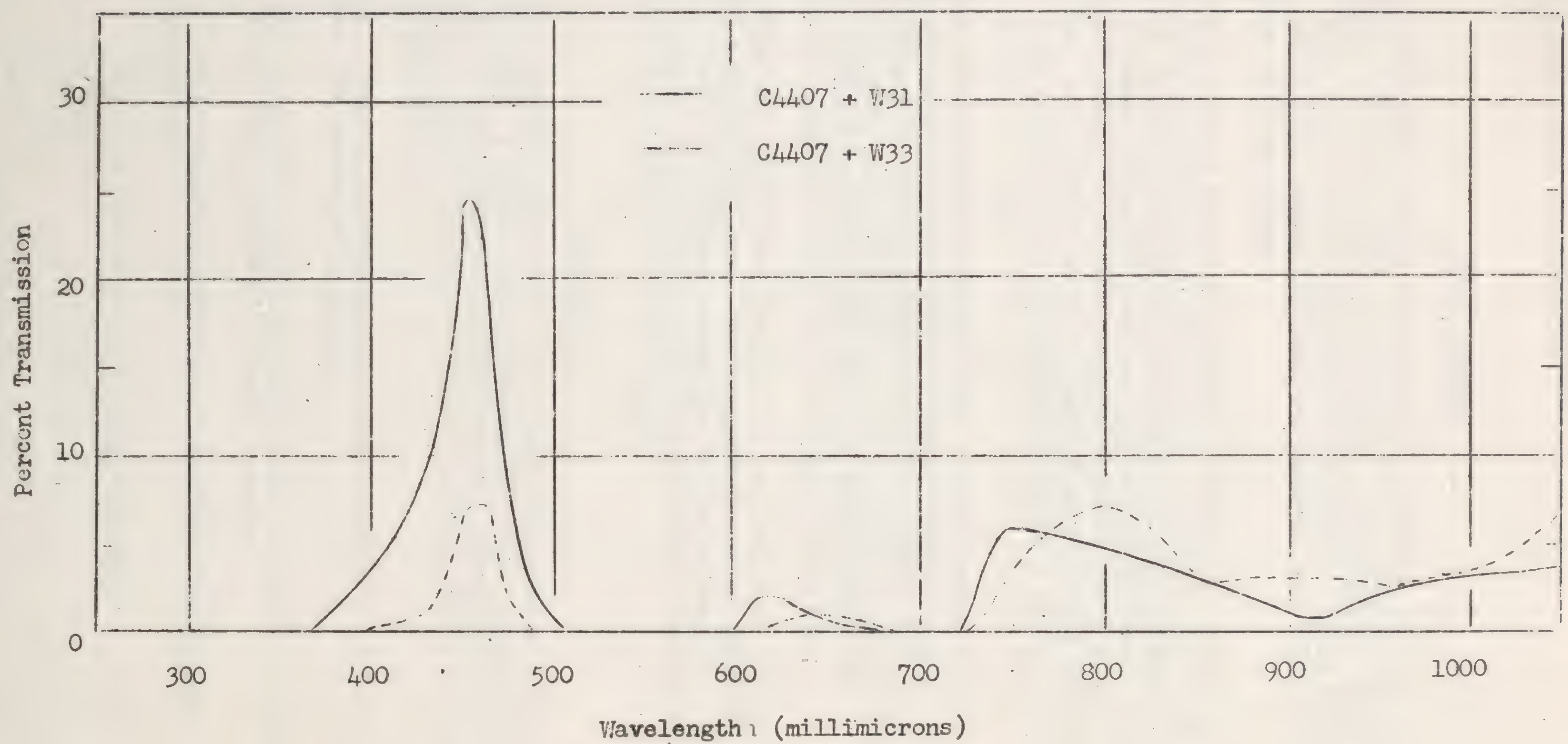
Both filters tested meet these specifications.

Spectral Transmission and Matching to Tracer Spectrum

Spectrograms of tracer material (SR 273) were taken with a logarithmic sector disc. All tracer bullets used in the trials carried tracer material of essentially the same composition. The strontium component of SR 273 produces the particularly prominent orange and red portion of the tracer spectrum (601-677 millimicrons), and the bright line observed in the blue region (461 millimicrons). The weak bands in the green may be due to either the strontium or the magnesium component. It has been claimed that the tracer spectrum differs considerably, in relative band intensity, when burned in standing and in moving air. The tracer material was burned in the laboratory in a stream of air to simulate, to some degree, the burning of a tracer bullet when fired from a gun.

Both the filter combinations tested give maximum transmission at points prominent in the blue or blue-green and the red regions of the tracer spectrum and marked attenuation of wavelengths above and below these regions as is shown in Figure I. The passage of the bright line in the blue region (461 millimicrons) would seem to be of the greatest importance in the selective observation of tracer material competing with the sun's spectrum.

FIGURE I



C4407 + W31
C4407 + W33
30
20
10
0
Percent Transmission
300
400
500
600
700
800
900
1000
Wavelength (millimicrons)

## Field Trials

Several field trials consisting of observing burning tracer material against the unoccluded sun through various goggles indicate the superiority of the two filter combinations described in the foregoing over other types, particularly the "red" goggle. Where glare conditions are bad the denser (#2) was the favorite and where less bad the less dense (#1) was chosen.

One series of trials was carried out with the sun at an angle of approximately 40 degrees from the horizon. As there were many high cirrus clouds, observations against the sun could only be made intermittently. Although #2 goggle gave less glare than #1 when looking directly into the sun, the tracer could be observed for a longer period of time, and aircraft could be located more quickly, when viewed through #1. All observers had difficulty in making a choice between these two goggles and stated themselves as satisfied with either.

The Variable-Density Goggle gave unsatisfactory results even against the sky using Practice Tracer. Better results were obtained using H. E. Tracer Ammunition (brighter-faster burning) but there was still difficulty in viewing the sun. The Variable-Density Red Goggle gave slightly better results than the Variable-Density Goggle although Goggles #1 and #2 were definitely superior.

Shipboard trials were carried out on a day with occasional sunshine and a bright hazy sky. With goggles #1 and #2, tracers, H. E. Tracer, could be followed across the ball of a hazy sun. It was slightly easier to look at the sun through #2, but tracers remained visible for a longer time through #1.

## Conclusions

(1) Corning Signal Green, No. 4407, (5mm. thick) with one thickness of either a Wratten gelatin filter No. 31 or Wratten gelatin filter No. 33 are more satisfactory for scanning a bright sky and for following tracer bullets into the sun than any other filter or combination of filters tried.

(2) These filter combinations meet British and most U. S. specifications for sun-scanning goggles.

(3) Goggle #2 (CG4407, 2.5 mm., + W33 + CG4407, 2.5 mm.) appears to be the choice for the following reasons:

(a) Denser than #1 hence less glare when looking directly into the sun.

(b) W33 filter is more stable than W31.

(c) Comfort gained when looking at sun through this goggle outweighs the slightly greater ability to see tracers and aircraft through Goggle #1.

(4) The filter combination suggested for goggles should replace the filters now in use on the gun sights.

(5) Attempt should be made to obtain a single stable plastic filter having the transmission characteristics of the CG4407 + W33 combination. This would permit the construction of goggles with a wider angle of vision than is possible with the glass-gelatin sandwich and would have other obvious advantages.

## References

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Solandt, D. Y., and Bunker, M. L., Progress report on special goggles for following tracer bullets. Appendix P, Proc. 3rd Meeting of Assoc. Committee on Naval Med. Research, N.R.C., Ottawa, 15 May 1944.
(2) Massachusetts Institute of Technology, Handbook of colorimetry. Camb. Man. Tech. Press, 1936.
(3) Peckham, R. H., Specifications for the sun-scanning device. Unpublished report, 16 August 1944.
(4) Admiralty Research Laboratory, Protection of the eyes from light and heat. A.R.L./R.1/83.04/O., 4 January 1944.
(5) Peckham, R. H., Protection against solar radiation. Proc. 5th Meeting, Army-Navy-OSRD Vision Committee, 16 September 1944.
(6) Blum, H. F., Solar energy reaching the retina. Proposed spectral curve for testing sun-scanning glasses. Proc. 4th Meeting, Army-Navy-OSRD Vision Committee, 27 July 1944.

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Discussion:

Several members commented on the high transmission of visible light by the goggles.

Lt. Comdr. Peckham thought the goggles would be very effective with a clear sun and clear atmosphere, but he was concerned about the effect of the selectively high transmission in the blue on visibility during fog. Comdr. Solandt stated that trials of the goggles were made under conditions of haze, and no accentuation of haze resulting from the use of the blue-green filter could be noticed. Dr. Hecht pointed out that there is no difference in visibility through most of the haze encountered in service situations resulting from the wavelength used. In answer to Dr. Bray, he stated that the particle

sizes in the smoke of gunfire are probably no different from ordinary haze.

In reply to a question concerning the length of time a viewer can look at the sun, Dr. Solandt stated that an after-image occurs after about a minute of looking at the sun, but that these goggles are for gunners, not for sun watchers. Dr. Blum asked if any determination of safe transmission figures had been made from these data. Dr. Solandt replied that more experience is needed before such determinations can be made.

Dr. Hecht pointed out that the emmotropic eye cannot accommodate for infinity with any degree of precision. A negative lens might sharpen the image. Comdr. Solandt indicated that they would follow up the suggestion to grind a diopter of negative correction in the lens. Lt. Comdr. Peckham protested that if the lens is ground for the blue, the red will be out of focus.

Lt. Chapanis reported that the AAF has evolved a sample of infrared absorbing plastic, yellowish in color, which has a transmission of 10% in the range 800 to 1500 millimicrons and 80% in the visible. It has not yet been determined how easily the material burns, how much heat it absorbs, and how easy it will be to manufacture.

## 5. THE SUN SCANNING PHOSPHOR TELESCOPE OR ICAROSCOPE

The following interim report on NDRC Contract OEMsr-1219, Institute of Optics, University of Rochester, was prepared by Dr. Brian O'Brien.

An optical volume limiting device for limiting the brightness of an image was devised privately in 1943 for sun scanning. The operation of this device is based on a property observed in many commercially available afterglow phosphors (luminous paints). The apparent fluorescence of such a luminous paint varies approximately as the intensity of the exciting ultraviolet or other short wavelength radiation, but the phosphorescent afterglow exhibits a phenomenon of saturation. Thus if two areas of the same sample of luminous paint are exposed to skylight and direct sunlight respectively, and then removed to the dark, the phosphorescent afterglow of the area exposed in the sun will be little if any brighter than that exposed simply to skylight. This effect is very noticeable even a few seconds after removal of the phosphor from the exciting light.

This principle of phosphorescence saturation has been utilized in a telescopic device, named the icaroscope, for viewing the sun and surrounding sky. An image of the sun and surrounding sky is formed on a phosphor screen by means of a suitable objective lens, and a rotating shutter between lens and screen intermittently exposes the phosphor screen to the incident illumination. A second rotating shutter, connected to the first, exposes the phosphor screen to view only at such times as the shutter in the illumination beam is closed, so that the phosphor screen becomes visible only by virtue of its phosphorescent afterglow. A somewhat analogous principle has long been utilized in so-called phosphoroscopes for observing the short time afterglow of phosphorescent materials. If the phosphor selected exhibits a bright but relatively short duration afterglow, and if the rotating shutters are operated so fast that no visible flicker occurs, the observer will see the phosphorescent image as though in steady illumination. If provided with a suitable eyepiece and erector system, the device becomes a useful telescope.

Tests with such an arrangement indicated considerable practical possibilities even with commercially available phosphors, so the development was presented together with assembly drawings to Section 16.5, NDRC, at its meeting on June 20, 1944. The Institute of Optics was requested to incorporate work toward further refining of the device into existing contracts OEMsr-81 and OEMsr-1219

An instrument was constructed according to these draw-

ings and was demonstrated to Section 16.5 at its meeting September 29, 1944, using a screen of commercial phosphor material. At this time work was in progress under OEMsr-81 to develop new phosphors better suited to service application. The instrument utilizes a cemented doublet telescope objective of 4 inch clear aperture and 12 inch focal length especially designed for optimum performance at the violet end of the visible spectrum. This covers a real field of 7 degrees total angle, the phosphor screen being slightly concave toward the objective to secure optimum image quality. The illuminating and viewing rotating shutters consist of two sector discs rigidly connected to a single motor shaft, and so placed that the plane of one disc is just in front, and the other just behind, the phosphor screen. The screen itself consists of a thin coating of phosphor on an orange yellow glass of such characteristics as to transmit quite freely green and yellow light emitted by the phosphor, but absorbing very strongly blue, violet, and ultraviolet radiation which excites the phosphor. In addition to this precaution for the reduction of scattered light, great pains have been taken in the design of the objective mount and all other parts of the instrument to reduce scattered light to an absolute minimum. These precautions are necessary because of the enormous difference between sun and sky brightness.

The eyepiece must perform as a simple magnifier rather than as a telescope eyepiece, since in this instrument the exit pupil is not related in size or position to the entrance pupil of the objective. It consists of a special triplet of 2 inch focal length and very long working distance to permit an erecting system between eyepiece and phosphor screen. This consists of a special roof prism deviating the axis by 75 degrees instead of the conventional 90 degrees. This particular deviation has been selected to provide maximum comfort on the part of the observer in viewing objects anywhere between horizon and zenith, the direction of the view of the observer under these two extremes being 15 degrees forward of straight down and 15 degrees above the horizontal respectively. The above combination yields an erect image at a magnification of 6 power with a real field of 7 degrees in an instrument of compact form which is quite comfortable to use.

Request for development of a service type instrument of this form was made by Lt. Comdr. R. E. Burroughs, Readiness Section, CominCh, who suggested that a useful instrument would be one in which an average size military airplane could be seen either against the sun or the surrounding sky when at a line of sight distance of 25,000 feet from the instrument. Such a performance requires that an object approximating a 10 foot diameter circle shall be visible at this distance, and corresponds to an image on the phosphor screen approximately 1/200 of an inch in diameter. The present instrument meets this requirement.

The brightness of the surface of the sun as seen through an average clear sky at sea level is approximately 500,000 lamberts, while the brightness of the blue sky some distance from the sun under the same conditions will be of the order of 5 lamberts. Immediately adjacent to the limb of the sun under the best sea level clear conditions the brightness of the sky will range from 30 to 150 lamberts, averaging perhaps 50 lamberts. Thus there is a drop in brightness in passing from the edge of the solar disc to the adjacent sky of approximately 10,000 fold, and an additional drop of tenfold more in passing from a point very near the sun to a location in the sky some distance away. The icaroscope must thus give images of useful but not dazzling brightness with an illumination range on the phosphor screen of 100,000 to 1. The best commercially available phosphors in the present instrument yield an apparent image brightness of about 1/4 millilambert from an area of the sky with original brightness of 5 lamberts. While this is a sufficient image brightness for clear visual observation, a brightness higher by five or ten fold would improve visual performance. Using such a commercial phosphor the brightness of the image of the sun is of the order of 20 millilamberts, or some eighty times brighter than the image of the sky. Thus the real brightness range between sun and sky of 100,000 fold has been compressed by the volume limiting principle of the instrument to an image brightness range of about 80 fold.

The compression in brightness range of the image as compared to the object would result in a very serious loss of contrast were it not for the fact that substantially all of this compression occurs at brightnesses of object greater than one or two hundred lamberts. Thus there is substantially no loss of contrast for all brightnesses occurring in the sky even up to the very limb of the sun. This is followed by an enormous reduction in contrast for object brightnesses between 500 lamberts and 500,000 lamberts. As a result, an airplane silhouette is quite visible against the sky far from the sun, against the sky at the very limb of the sun, and against the solar disc itself. On the other hand, a sun-spot which is very much less bright than the sun itself but far brighter than the surrounding sky, is quite invisible in the instrument.

Very recently under contract OEMsr-81 it has been found possible to produce new phosphors of zinc-cadmium sulphide which yield efficiencies (image brightnesses) five or more times better than commercially available phosphors, with no appreciable sacrifice in time constants or resolving power. This adds very materially to the ease of use of the instrument and to the performance of the eye when viewing the phosphor screen. After considerable difficulty a production method for the new phosphors has been developed together with a satisfactory procedure for producing the necessary thin screens. Further improvement of the phosphors would be highly desirable and work on this point is going forward actively.

To date only one instrument has been constructed using a relatively heavy sector operating motor. This instrument weighs 12-1/2 pounds complete with motor. At the request of the Navy Department, design of a lighter weight model has been completed. This uses the same optical system, but incorporates several mechanical improvements including a much lighter motor. Although designed to be completely weather-tight for shipboard operating conditions, the estimated weight of the new instrument is only 9 pounds. The design permits the instrument to be used either hand-held or in a simple alt-azimuth swivel mount. The input power requirement for the motor is approximately 10 watts so that operation from a portable storage battery or even from dry batteries is quite feasible.

The Navy Department has indicated a desire to procure at once relatively large numbers of this instrument, and tests and experimental work are in progress in connection with the problems encountered in initiating production. Lt. Comdr. Burroughs has requested that development work on a binocular form of the instrument be undertaken. A start has been made, but it is expected that several months will elapse before a fully engineered binocular unit will be forthcoming. Production on the monocular form will probably be well under way before first service tests on the binocular can be undertaken.

# 6. COCKPIT AND INSTRUMENT PANEL ILLUMINATION IN MILITARY AIRCRAFT

The following report was prepared and presented by Dr. H. K. Hartline.

Good night vision in aircraft demands careful design and installation of instrument and cockput lighting. Dazzle and loss of dark adaptation from viewing the lighted instrument dials and maps, and scatter and reflection of light in the windshield can cause serious impairment of the ability to detect faint objects at night. This impairment of night vision is not always recognized, especially by airmen whose night flying experience has included only operations from brightly lighted airfields, over lighted airways and lighted cities and coutryside, with air traffic plainly marked. Indoctrination of flying personnel in the principles of night vision is of prime importance, but it is also necessary to equip the aircraft with properly engineered lighting systems. Aircraft designers have for the most part neglected this requirement.

Proper cockpit illumination for military night flying requires the elimination of all light not absolutely essential to the operation of the aircraft. Much can be accomplished by careful attention to simple details -- eliminating light leaks, masking warning and pilot lights, placing light sources so as to avoid glare reflections, providing even illumination on essential instruments, and eliminating the illumination of less important ones. Complete control of illumination is very important; it must be possible to reduce the brightness of instrument markings to the point where they are just barely legible on the darkest night and still provide adequate range for easy reading in bright moolight and twilight. It is now well known that the use of orange or, better, red light for instrument and map illumination provides considerable reduction in the amount of light that affects the night visual mechanism, without sacrificing legibility. Design of instrument dials has greatly improved; unnecessary markings have been eliminated and greater legibility has been achieved. Studies being conducted at Randolph Field offer promise of still further improvement in this direction. Development of simplified and consolidated instrument presentations will likewise improve conditions for the night flyer.

Satisfactory systems of cockpit illumination are in use to a limited extent in our services. The lighting systems in the Navy night-fighters have been carefully engineered; indirect illumination of the instrument panel by red light is employed. This system has been much improved in recent years, but it still remains difficult to install properly, and at best there are inequalities of illumination and high lights which cannot help but impair legibility somewhat. The

use of red light, however, probably more than offsets these disadvantages. Except for the night fighters (and a few other Navy types) Navy and Army aircraft are predominantly equipped with fluorescent (U-V excited) instrument lighting. To the best of the writer's knowledge, the old style green fluorescent marking materials still predominate; the new "orange" material has been slow to appear in operations, even in the Army night fighters. Fluorescent lighting has the advantage of giving a very even illumination, with dial markings of high contrast and pleasing appearance. It is easy to install (although glare reflections must be avoided). Adequate range of brightness control is not provided in existing installations, but this could be corrected. Its chief disadvantages are that it cannot provide red markings, and that the exciting ultraviolet is by no means "black" light. Even the new orange fluorescent material, if it ever gets into universal use, is rather more yellow than orange, although a great improvement over the green. The full advantage of deep red light probably cannot be achieved by fluorescent lighting, because of the low visual efficiency of the long wavelengths. As it is, the exciting ultraviolet must encroach on the deep violet end of the visible spectrum to achieve adequate excitation, and this deep violet light is the worst possible for the night visual mechanism. Scattered ultraviolet, in addition, produces fluorescence of the ocular media, filling the field of view with a luminous haze which contributes to the impairment of night vision and at higher brightness levels is annoying. The R.A.F. uses fluorescent lighting, but its use is confined to the lowest levels of marking brightness. When brighter lighting is needed, red floodlights are turned on. Orange fluorescent material is universal. Self-luminous markings have been eliminated entirely, and an auxiliary electrical supply is provided for standby. This system seems to the writer to be a good compromise, and one worth copying by our own services.

Choice of a system of cockpit lighting involves many engineering and practical factors difficult to assess. Comparison of relative scotopic and photopic brightnesses of the dial illumination is useful, but it is still necessary to determine whether a given installation impairs night vision to a degree that is significant in practice. It is for this reason that a Navy project has been set up to compare a fluorescent lighting system with a Navy indirect red instrument panel under conditions that imitate actual operations. A preliminary experiment has been done on the effect of these two instrument panels on the time required for an observer to pick up a faint target. This will be described in detail in the following article; the photometric procedures employed are worth mentioning briefly at this point. In this experiment the two instrument panels were adjusted to equal brightness of markings, and the effect on night vision, as measured by pick-up time, was determined. To make the initial adjustment, a marking brightness photometer was devised which can be used in actual installations without interfering with the floodlighting

of the panel. A reflector sight was arranged so that an image of roughly similar size and shape to one of the markings, and of known variable brightness could be made to appear next to a dial marking, and adjusted to match the brightness of the marking. While not as accurate as conventional photmetric determination, 10% accuracy can be achieved at levels of 10 µ l and greater. The photometry employs foveal vision; colored filters calibrated spectrophotometrically must be used to obtain a good color match. This instrument measures the difference in brightness (photopic) between the marking and its background, which for comparable dials is the principal factor determining legibility.

The low brightness photometer used for setting the "sky" brightness in the experiment is an attachment that has been improvised for a Macbeth illuminometer. The field of the instrument is large (20°), with the unknown brightness appearing in a zone between two areas of known variable brightness that differ by 30%. Match is made by adjusting the known brightnesses until the unknown is bracketed between them; equality of contrast is the final criterion. This type of field is much easier to use, and somewhat more accurate at low levels than a simple divided field requiring an equality brightness judgment. Measurements can be made down to .001 µ l.

The total illumination emitted by the instrument panel, measured at the pilot's eyes in scotopic units, may be expected to be correlated with the impairment of night vision caused by the panel. For similar panels illuminated differently the correlation should be high; different panels may be expected to bring in a geometric factor, but the total illumination should still furnish a good index of the degree of interference with night vision that may be expected. This illumination can be measured by the low brightness photometer. In the experiments to be described a white porcelain diffuse-reflecting plate (Macbeth illuminometer) was set up in the plane of the pilot's face and the illumination falling on it from the lighted instrument panel (adjusted to a known value of marking brightness) was measured. Since the brightness was very low, scotopic values were obtained automatically regardless of the kind of illuminant. (A non-fluorescing screen, such as porcelain, is necessary to avoid errors when using ultraviolet illumination. This measurement, of course, fails to take into account the fluorescence of ocular media caused by the ultraviolet floodlighting.) The combined use of the marking brightness photometer to adjust the photopic brightness level of the dials and the low brightness photometer to measure the scotopic illumination affecting the pilot's eyes, should make it possible to assess the acceptability of actual lighting installations in aircraft intended to operate at night.

## 7. AN EXPERIMENTAL COMPARISON OF ULTRAVIOLET AND INDIRECT RED ILLUMINATION SYSTEMS FOR AIRCRAFT INSTRUMENT PANELS

The following report was prepared and presented by Lt. John A. Bromer.


### SUMMARY

Procedure

A comparison was made between an ultraviolet and an indirect red illumination system for aircraft instrument panels in terms of their effects on the pilot's ability to spot faint targets against the night sky.

Targets were first spotted against a background of projected starlight, and then against a background of even illumination. Spotting time was measured after the pilot looked at either an indirect red or ultraviolet illuminated panel.

Instrument markings used with both illumination systems were prepared with orange fluorescent paint, specification AN-L-1a. This paint is used by both the U. S. Army and Navy on panels of night operating aircraft. Illumination was provided by two C-5 (AN3038-1) mercury-vapor lamp assemblies in the U-V cockpit and by fifteen 3-v. incandescent lamps in the indirect-red panel.

Results

The indirect-red system was found to have less effect on dark adaptation than the ultraviolet system. The superiority of the red system was demonstrated under all experimental conditions tried.

A method of modifying the U-V system to reduce the light level from the C-5 lamps is described. This modification should eliminate excessive amounts of visible light in the U-V illuminated cockpit and can be effected by Army and Navy squadrons using the C-5 lamp for illumination on night operations.


### PURPOSE

The purpose of this experiment was to compare two systems of instrument lighting for night-operating aircraft: an indirect red system, and an ultraviolet floodlighting system, in which the instrument markings were orange fluorescent.

### APPARATUS

Two Link Trainers were used throughout the experiments. These trainers were placed in the Fels Planetarium of the Franklin

Institute, Philadelphia, for use by the Special Devices Division, BuAer, Project 9T.

The original Link instrument panels were replaced by specially prepared panels similar in instrument arrangement to the panel of the TBF-3. The two panels were identical except that one was floodlit by two C-5 lamps placed at either side of the panel and about eight inches from it, while the other was illuminated indirectly by fifteen red incandescent lamps hidden behind a dummy, or reflecting panel of dural. The red lamps were placed in an intermediate lucite reflecting sheet which transmitted the light fairly evenly to all the instrument dials.

A coaming of black cardboard, extending seven inches in front of the panel, was placed above each panel of the windshield. (The opaque hoods of the Link Trainers were replaced with plexiglass canopies.)

Targets were provided by a projector (used in Planetarium demonstrations) which threw an image in the form of an arrow on the Planetarium dome. This image had an area of about 90 square cm. Brightness of the image was controlled by a delicate ammeter, and the brightness was reduced to near the limen by means of a neutral density filter with a logarithmic value of three.

The starlight background used in the experiment was provided by the star projectors of the Planetarium instrument. Even illumination was provided by a small frosted lamp placed on the top of the Planetarium instrument. Under starlight conditions, the average level of brightness on the dome was 0.05 microlambert (the brightness of the dark, starless area of the dome on which the arrow image was projected was about 0.02 microlambert). Under the condition of even illumination, the brightness of the dome was held at 0.1 microlambert, which is about the level of the moonless sky under starlit or overcast conditions -- away from city lights.

The target brightness was varied in the experiment, but the average brightness exceeded that of the background, at the level generally used, by 0.02 microlambert under starlight conditions and 0.06 microlambert under overcast conditions. (Delta B = 0.02 and 0.06, respectively.) The target was presented in four fixed positions within the frame provided by the windshield.

## PROCEDURE

All subjects were completely dark adapted (30 min.) before each part of the experiment. The subjects, all trained in visual experimentation, were seated in the Link Trainers at a distance of about seven meters from the edge of the Planetarium dome. Each

subject was first given preliminary practice to demonstrate the experimental technique and permit him to become acquainted with the problem. During this practice he was asked to spot the dimly illuminated target at various levels of brightness until a level was found at which his average "pick-up time" (time taken to spot the position of the target on the dome) was about four seconds. This preliminary practice usually consumed all of the first experimental period of two hours.

The subject was directed to scan the panel for 30 seconds before searching for the target and was trained to time himself by starting an accurate timer as he looked up from the panel and stopping it as soon as he found the target.

After the preliminary trials had given an indication of the proper setting of the target brightness for an average pick-up time of four seconds, the subject was given 24 trials, 12 in the red-illuminated cockpit and 12 in the U-V cockpit. Six of the 12 trials in each cockpit were control trials, in which the subject looked at an unilluminated panel for 30 seconds before attempting to spot the target. In the other six trials the subject looked at either the red or the U-V illuminated panel for 2 min. or longer and then searched for the target. Control and test trials were run in an ABBA order, with adequate time for readaptation after each exposure to an illuminated panel. Ratios were then computed, in which the average pick-up time after exposure to the illuminated panel was divided by the average pick-up time in the control series. For each experimental session two ratios could be computed:

$$(1)\quad \frac{\text{Pick-up time after exposure to the Red panel}}{\text{Pick-up time on control trials in the same cockpit}}$$

$$(2)\quad \frac{\text{Pick-up time after exposure to the U-V panel}}{\text{Pick-up time on control trials in the same cockpit}}$$

The background and target brightnesses were held constant throughout each experimental period.

In the second experimental session, the same procedure was followed, except that generally 36 trials were run, 18 in each cockpit. Two sessions thus provided 60 trials, including 15 Red trials, 15 control trials in the same cockpit; 15 U-V trials, and 15 control trials in the same cockpit.

### Tests under Starlight Conditions

The procedure already described was first used under starlight conditions — when the dome of the Planetarium was illuminated solely by the light of the projected stars. The stars were used at the full available brightness, which gave an overall illu-

mination somewhat less bright than the true starlit sky.

As it was desired to test the best Red and U-V systems under optimal working conditions, the first trials were run with an unequal level of instrument-marking brightness on the two panels. One of the defects of the U-V system, as used in Army and Navy one- and two-place planes, is that two C5 lamps on 28 v. DC at eight inches from the panel (a typical distance in this type of installation) provide too much illumination on the instruments, even when the lamps are operated with the filters closed and rheostats set at full dim. Thus the brightness of markings on the U-V panel could not be decreased beyond 30-60 microlamberts. The red panel, on the other hand, provides a full range of dimming from 0 to 150 or 200 microlamberts or more. Under starlight conditions (as reproduced approximately in the Planetarium) it was found that the red panel could be easily read when the brightnesses were 10-20 microlamberts. Thus the first set of runs was made with the brightness of the markings about three times as great on the U-V as on the Red panel.

When the results of the first run indicated that the U-V system had a greater detrimental effect on pick-up time than the Red system, it was decided to equate the two panels in terms of marking-brightnesses and make a second series of runs. In this second series the brightness of the Red panel was increased so that the markings measured 25-80 microlamberts, a range comparable to that found with the U-V panel at full dim. In this report the 10-20 microlambert will always be referred to as the Dim Red panel; the 25-80 microlambert panel, as the Bright Red panel.

### Tests under Overcast Conditions

In a third series of runs the same target was used but the background was changed. The evenly-illuminated surface of the Planetarium dome was at a set brightness of 0.1 microlambert. Both the red and the U-V panels were lit so that the marking brightnesses were equal — at about 30-60 microlamberts. That is, only the Bright Red panel was used for comparison with the U-V. The brightness on both panels was somewhat above the minimum requirements for seeing the instruments efficiently at a sky brightness background of 0.1 microlambert.

## RESULTS

### Tests under Starlight Conditions

The average pick-up times for each subject under each of four experimental conditions are shown in Table 1. The times represent the average response time to the target (1) on 15 trials after exposure to the Dim Red panel, (2) on 15 control trials in the same cockpit, (3) on 15 trials after exposure to the U-V panel, and (4) on 15 control trials in the same cockpit.

TABLE I

A Comparison of the Dim Red and U-V Panels under Conditions of Starlight Illumination

| Subject | Pick-up Times (seconds) | | | | | | | | Ratios | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | | Red | | Control | | U-V | | Red to Control | U-V to Control |
| | Mean | Sigma | Mean | Sigma | Mean | Sigma | Mean | Sigma | | |
| HKH | 4.1 | (1.9) | 4.1 | (1.6) | 3.7 | (2.4) | 10.9 | (6.5) | 1.00 | 2.96 |
| DS | 3.1 | (1.7) | 3.8 | (2.0) | 3.8 | (2.0) | 8.8 | (4.5) | 1.23 | 2.31 |
| JAB | 5.6 | (2.2) | 5.7 | (3.2) | 4.8 | (3.3) | 10.5 | (5.3) | 1.03 | 2.18 |
| IB | 5.9 | (1.6) | 6.7 | (2.6) | 7.5 | (4.8) | 7.4 | (3.8) | 1.12 | 0.99 |
| [illegible] | 5.7 | (3.8) | 5.6 | (3.5) | 4.5 | (3.2) | 17.5 | (12.6) | 0.98 | 3.36 |
| MV | 3.9 | (1.8) | 4.5 | (2.3) | 3.4 | (2.3) | 6.2 | (2.7) | 1.17 | 1.82 |

It will be observed that five of the subjects show an advantage for the Dim Red panel over the U-V.

Throughout the experiments the trials in which the subject thought he had spotted the target but did not and called an incorrect position were not used in computation of average pick-up times. Errors were very infrequent -- averaging about 1-2 per cent of all responses on control trials. Errors in the Dim Red trials also averaged about 2 per cent, but on the U-V trials the errors amounted to about 8 per cent of all trials.

When ratios were made for each day's run, in which ratios were computed as follows:

$$(1)\quad \frac{\text{Pick-up time after exposure to the Dim Red panel}}{\text{Pick-up time on control trials in the same cockpit}}$$

$$(2)\quad \frac{\text{Pick-up time after exposure to the U-V panel}}{\text{Pick-up time on control trials in the same cockpit}}$$

it was found that of 13 ratios computed, 12 showed an advantage for the Dim Red panel and one showed an advantage for the U-V panel.

In the second series of runs under starlight, the brightness of the Red panel was equated to that of the U-V. This Bright Red panel, on which the marking brightnesses ranged from 25 to 80 microlamberts, was tested in place of the Dim Red panel used in the first series. No additional trials were run with the U-V, but the data obtained on the U-V panel in the first series for the same subjects who participated in the second series was employed for purposes of comparison with the Bright Red panel.

The results are shown in Table 2. Four of five subjects showed an advantage for the Red system over the U-V, even when the Red system was operated at a brightness level higher than necessary under starlight conditions. Errors were almost four times as frequent on the U-V panel as on the Bright Red panel.

__Tests under Overcast Conditions__

When the U-V and Bright Red panels were compared in their effect on pick-up time of the arrow target against a background of even illumination (0.1 microlamberts), the data shown in Table 3 were obtained.

Table 3 demonstrates again the superiority of the Indirect Red system over the U-V. Five of five subjects showed an advantage for the Red panel. A count of ratios computed from each day's runs reveals that of 17 such ratios computed, 16 favored the Red panel. Errors were four times as frequent on the U-V panel as on the Red.

TABLE II

A Comparison of the Bright Red and U-V Panels under Conditions of Starlight Illumination

| Subject | Pick-up Times (seconds) | | | | | | | | Ratios | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | | Red | | Control | | U-V | | Red to Control | U-V to Control |
| | Mean | Sigma | Mean | Sigma | Mean | Sigma | Mean | Sigma | | |
| AS | 8.7 | (4.9) | 10.5 | (4.4) | 11.0 | (5.4) | 17.4 | (9.7) | 1.21 | 1.58 |
| EN | 3.2 | (2.2) | 3.1 | (1.8) | 4.5 | (3.2) | 17.5 | (12.6) | 0.98 | 3.36 |
| JAB | 4.9 | (2.9) | 5.0 | (3.1) | 4.8 | (3.3) | 10.5 | (5.3) | 1.01 | 2.18 |
| IB | 4.1 | (1.2) | 5.0 | (2.2) | 7.5 | (4.8) | 7.4 | (3.8) | 1.22 | 0.99 |
| MV | 5.3 | (6.2) | 3.9 | (1.9) | 3.4 | (2.3) | 6.2 | (2.7) | 0.72 | 1.82 |

TABLE III

A Comparison of the Bright Red and U-V Panels under Conditions of Overcast Illumination

| Subject | Pick-up Times (seconds) | | | | | | | | Ratios | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | | Red | | Control | | Red | | Red to Control | U-V to Control |
| | Mean | Sigma | Mean | Sigma | Mean | Sigma | Mean | Sigma | | |
| MV | 6.2 | (3.8) | 5.7 | (2.2) | 3.6 | (1.7) | 5.3 | (2.6) | 0.92 | 1.48 |
| JAB | 4.2 | (2.0) | 5.1 | (3.0) | 4.1 | (2.6) | 7.8 | (4.1) | 1.20 | 1.91 |
| DS | 6.3 | (3.7) | 8.1 | (5.9) | 3.8 | (3.3) | 14.2 | (12.2) | 1.28 | 3.75 |
| EN | 5.1 | (2.7) | 7.7 | (7.2) | 5.9 | (4.1) | 19.2 | (8.8) | 1.52 | 3.28 |
| AS | 4.9 | (3.7) | 7.3 | (3.6) | 4.9 | (2.4) | 11.9 | (7.7) | 1.51 | 2.43 |

The evident superiority of the Red Indirect panel over the U-V panel in this experiment may be explained by several supplementary findings. One was that even when the brightness of the markings on the two panels have been equated, the total amount of light reaching the pilot's eyes is about 10 or 15 times as great in the U-V panel as it is in the Red. This fact was demonstrated by measuring with the Hartline Low Brightness Meter the amount of light reflected from a Macbeth opal plate placed in the approximate position of the pilot's head in the two cockpits, when the level of marking brightnesses was about 30-60 microlamberts on each of the two panels. It has been suggested by Hartline that the effect on pick-up time is a function of the total amount of light reaching the pilot's eyes.

It has also been suggested that the effect of U-V light in prolonging the pick-up time may be influenced by the fluorescence of the crystalline lens of the pilot's eyes. We are beginning a study of this phenomenon to see if any relationship between the effect of the U-V and the amount of lens fluorescence can be ascertained.

Evidence obtained in this study (but not reported) indicate that the U-V floodlighting on the orange fluorescent paint gives a more effective contrast than the red figures give against the black background on the dials of the Indirect-Red panel. If a better range of dimming than that on the C5 lamp is provided, it is likely that a level of illumination could be found at which the panel would be quite legible under starlight illumination and still have little or no effect on dark adaptation.

Special Note on Modification of the U-V Floodlighting System

For the benefit of squadrons already operating in the field with C-5 mercury-vapor floodlighting on orange fluorescent markings, an attempt was made to modify the more or less standard U-V system for more effective operation. This was accomplished as follows:

A film filter of about 10-25 per cent total transmission was prepared by exposing a strip of 35 mm. film for a short time. A circular section of this strip was then cut out and placed over the front of the C5 lamp. With this extra filter, there is still adequate light for easy reading of fluorescent maps or charts. The two lamps at the side of the cockpit were moved to a position about three or four inches from the instrument panel, and the dead spot in the center of the panel removed by adding a third C5 lamp with 10-25 per cent filter on a bracket extending about three inches out in front of the panel and just above it under the coaming. These three lamps will easily illuminate the 10 or 12 fundamental instruments needed for night combat or patrol operation. (It should be noted that the two lamps at the side of the cockpit should be placed high - to eliminate the danger of reflections off the instrument glasses.)

The coaming at the top of the panel, which can be made of flexible material, such as cardboard with rubber or rubber foam edge, etc., was wide enough to extend all the way across the top of the panel and about seven inches in front of it. The coaming in some aircraft may be made to extend 10 or more inches in front of the panel if necessary; in others it cannot be more than five inches deep. It must keep all reflections of the instruments off the windshield and other forward sections of the canopy.

## CONCLUSIONS

Under laboratory conditions approximating starlight and overcast night sky illumination, a comparison was made of the time required to spot faint targets against the sky background after looking at an indirect-red and an ultraviolet illuminated instrument panel. The indirect-red system showed an advantage in every case.

(This project was done for the Military Requirements Section, Bureau of Aeronautics. It was performed under the supervision of Lt. Comdr. C. F. Gell, MC, USN, Military Requirements Section, and Dr. H. K. Hartline, Johnson Foundation. Installation of the Link Trainer in the Planetarium was arranged by Special Devices Division, Bureau of Aeronautics, under authority of Project 9T.

The author appreciated the cooperation of the staff of the Franklin Institute in setting up this project and especially of Dr. Roy K. Marshall, Associate Director of the Fels Planetarium.)

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Discussion:

Lt. Comdr. Lee asked if the variation found by Lt. Bromer could be due to variation in brightness. Dr. Hartline explained that variation occurred because the measurements were not accurate psychophysical meaurements. It is very difficult to control or measure all the variables in such a study. When an array of instruments is causing simultaneous glare and one measure must be taken, the total quantity of light seems the best choice. Lt. Comdr. Lee pointed out that, according to Crawford's formula, selecting integrated illumination at the eye as the variable to be measured would only be satisfactory if the geometric area were constant.

In reply to Dr. Miles, Dr. Hartline explained that the panel lights were extinguished only for control measurements. Dr. Bray asked if flyers actually do turn out their panel lights in flight. Wing Comdr. Lee said that experienced night fighters do. Mr. Morse thought that air carrier pilots do not turn their panel lights out. Lt. Bromer added that pilots at Charlestown are instructed to keep their instrument panels at a very low level.

Dr. Hecht pointed out that the delay in picking up the target was due to two effects on dark adaptation: one resulting from previous exposure to the directly viewed instrument panel and the second resulting from the continuing illumination by the panel of the peripheral retina.

Dr. Miles asked if the target required parafoveal detection and whether there was any consistent variation in the angle of elevation of the target. Lt. Bromer explained that the brightness of the target was only 0.2 log $\mu\mu$ l above the terminal threshold and that subjects were trained to use rod vision. The target was presented at random in one of four positions, two above the horizontal line of sight and two below. In order to eliminate any learning factor, the subjects learned the four positions before the experiments. The subjects were required just to pick up the target; identification was not required.

Lt. Chapanis reported a criticism from the AAF that since the experimental set-up with the Link Trainer did not simulate conditions in a P-61, for instance, the results have limited application. In the P-61 the gunner is away from the instrument panel, and the pilot enclosure is not necessarily in the same position as it is in the Link Trainer. Lt. Chapanis suggested that the markings are more visible with the ultraviolet system, and that since many pilots turn on the U-V and then turn it off, it might then be dimmer than the results of the experiment indicate.

## 8. DEVELOPMENT OF INSTRUMENT PANEL ILLUMINATION

The following report was prepared and presented by Mr. A. L. Morse, Civil Aeronautics Administration.

The development of various means for illuminating aircraft instrument panels and cockpits has been studied by the Technical Development Division for a considerable time. This has included the installation of ultraviolet illuminators in a Boeing 247-D airplane together with the use of fluorescent markings of the instruments. In that installation various arrangements of U-V and red illuminators have been investigated through extensive night flying. Other developments involving the use of clear light, red light, U-V, and combination systems also have been investigated.

Considerable experience obtained by the armed services, the industry, and through our flight tests has indicated that none of the presently-used systems are entirely satisfactory. The use of ultraviolet has a detrimental effect on night vision which apparently is caused by the reflection back into the pilot's eyes of U-V from the cover glasses, instrument panel, and other objects in the cockpit. Attempts to develop red illumination have led to complicated electrical systems and as yet have not provided even illumination. Objectionable reflections still persist and added weight is involved.

Recently a different system of illumination has been investigated which appears particularly promising. This involves the use of retro-reflectivematerial for marking the instruments and other pertinent objects in the cockpit and the use of incandescent illuminators of extremely low intensity. The retro-reflective material has the characteristic of reflecting a large percentage of the light directly back at the light source. Thus, a very small lamp located near the eye of the observer causes the instrument markings to glow with considerable intensity and with very little illumination of other portions of the cockpit.

The use of a red filter is being investigated since physiological and service tests have indicated that red illumination has the least detrimental effect upon dark adaptability.

Because of the promise shown by the retro-reflective system of instrument illumination, it is planned to investigate further installation and illumination problems in this connection, and to develop types of retro-reflective materials of improved efficiency and greater ease of application.

## 9. THE PROGRAM OF INSTRUMENT RESEARCH AT THE AAF SCHOOL OF AVIATION MEDICINE

The following report was prepared and presented by Dr. Roger B. Loucks.

The current program of instrument research being conducted by the Department of Psychology, AAF School of Aviation Medicine, under directive of the Office of the Air Surgeon, has three major lines of development. The first aspect of the project has to do with problems of legibility of aircraft instrument dials. The second aspect of the program is concerned with the relative intelligibility or meaningfulness of different methods of indicating the attitude of the airplane and flight conditions. The third type of problem, which as yet is only in the planning stage, has to do with measurements of the efficiency of various patterns of instrument arrangement.

To a certain extent the three major phases of the program are characterized by distinctive experimental procedures. The relative legibility of various instrument dials is considered to be indicated by the accuracy with which a series of dial settings can be read during brief exposures of the dial. Starting with standard types of AAF instruments an effort has been made to determine the general characteristics of a particular class of dial which make for optimum legibility. Studies have been made of the size and thickness of scale markings, numerals and pointers, and of the spacing of scale markings and of numerals. Both artificial and fluorescent lighting have been used in these studies.

To establish the intelligibility of certain types of aircraft indicators, measurement is made of Link Trainer performance by means of a newly devised objective scoring system. Comparisons can thus be made between the scores yielded by one instrument, such as the standard type of artificial horizon, and other types of attitude indicators.

Ultimately, it is planned that additional validation material will be obtained from measurements taken during actual flight. Arrangements are now being made to take motion pictures of eye movements with the technique developed by Lt. William McGehee of the Navy, and to check the effectiveness of performance by means of certain flight recorders developed for this purpose.

The following reports from the AAF School of Aviation Medicine are available on request from the Office of the Air Surgeon, Hqs. AAF, Washington 25, D. C.:

Project No. 265, Rpt #1, Legibility of Aircraft Instrument Dials: The relative legibility of tachometer dials.

Project No. 265, Rpt #2, Legibility of Aircraft Instrument Dials: A further investigation of the relative legibility of tachometer dials.

Project No. 266, Rpt #1, Effect of the Shape of Handles and Position of Controls on Speed and Accuracy of Performance.

Project No. 286, Rpt #1, Legibility of Aircraft Instrument Dials: The relative legibility of various climb indicator dials and pointers.

Project No. 325, Rpt #1, Legibility of Aircraft Instrument Dials: The relative legibility of manifold pressure indicator dials.

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Discussion:

Dr. Miles asked whether pilots locate switches and controls in the cockpit by motor adjustment or by vision. Mr. Morse pointed out that the retro-reflective material he described can be put on switches and controls as well as on dials. Lt. Comdr. Dyke asked if any work had been done on differentiating between controls by sense of touch -- with rough and smooth surfaces, for example. Dr. Loucks answered that some work has been done at SAM on ease of distinguishing shape although position is the most important factor. A report on this work will be available shortly.

Mr. Darr expressed an interest in the development of red radioactive material. Dr. Hartline stated that radium markings usually have a brightness between 2-5 microlamberts.

Wing Comdr. Lee pointed out that self-luminous radium is not useful as a standby lighting system because if it is sufficiently bright to see instruments in full moonlight, it will be too bright for adequate adaptation on moonless nights.

# ABSTRACTS

## 32. THE EFFECT OF EXTRANEOUS ILLUMINATION UPON DETECTION OF SIGNALS ON AN A-SCAN OSCILLOSCOPE

Lindsley, Donald B., et al., Applied Psychology Panel, NDRC, Project SC-70, NS-146, Research Report No. 13, 18 October 1944, 7pp. (confidential).

The effect of extraneous illumination on the detection of signals of different amplitude (including those of near-threshold height) on an A-scan oscilloscope has been studied. Three levels of ambient illumination (producing approximately 0, 1, and 22 apparent foot candles brightness on the scope face) and three levels of scope or trace brightness (low, intermediate, and high) were used.

Adding illumination to the scope face produced neither improvement nor deterioration of signal detection ability, except in the case of maximum illumination combined with minimum trace brightness, which caused a reduction in signal detection. Since this combination would probably never be chosen for operation, it may be concluded that added illumination will not adversely effect performance under normal operating conditions. On the other hand, it has been demonstrated that conditions of added illumination may be permitted without loss of detection whenever this is necessary or convenient, as may occur when others are working in the same room, when the radar operator is required to read or manipulate controls, or when it is desired to obtain the specific visual benefits thought by some individuals to result from conditions of general illumination of the work space.

## 33. HEAT ABSORPTION BY FILTERS

Admiralty Research Laboratory, Teddington, A.R.L./N.1/83.04/O., 15 September 1944, 7pp. (confidential).

Measurements have been made on various filters with regard to the protection of the eye from infrared radiation. The report concludes: (a) The green heat absorbing glasses used in Great Britain offer good protection against infrared. Measurements on enemy filters show that they have obtained a reasonable degree of heat protection with less coloration. (b) Care must be excercised in using the standard Admiralty neutral glasses; their heat protection is low. (c) Ordinary color glass filters, as a rule give

little heat protection. (d) Plastics give very little heat protection. (e) Plastics, specially designed to absorb infrared, e.g. by the introduction of colloidal silver, show good heat protection but tend to be diffusing and are not satisfactory from the visual point of view.

## 34. PARALLELOGRAM MOUNTING OF REFLEX SIGHT FOR 50 CAL. ANTI-AIRCRAFT MACHINE GUN

Brackett, Lt. Col. F. S., Armored Medical Research Laboratory, Fort Knox, Report on Project No. 6-15, 14 October 1944, 4pp. (not classified).

A mount has been developed which places the reflex sight above the smoke of gunfire, is convenient to the gunner (the eye can be held within one or two inches of the window), and satisfactorily removes shock disturbance. Tests indicate that boresighting and alignment are adequately attained. It is recommended (1) that the parallelogram mount be adapted for armored vehicles employing 50 Cal. machine gun for anti-aircraft protection, and (2) that platforms be provided in armored vehicles to secure the proper height for the use of subject parallelogram sight.

## 35. DETERMINATION OF SKY/SEA BRIGHTNESS CONTRAST AT WHICH THE HORIZON IS VISIBLE AT NIGHT (a) WITH NAKED EYE AND (b) WITH BINOCULARS

Admiralty Research Laboratory, Teddington, A.R.L./R.1/85,13/O., 4 September 1944, 13pp. (confidential).

It is known that, even when all appropriate corrections have been made for loss of light in transmission etc., the increase in range of detection of ship targets with binoculars is not as great as that calculated from the magnification. The experiments here reported had two objectives: (a) to see whether binoculars behave in the way theoretically predicted in relation to contrast discrimination between two equal areas of field, and (b) to obtain fundamental data (for use in connection with other calculations) on the minimum contrast perceptible at low brightness when the field is viewed with both eyes, free scanning is allowed, and distant accommodation used. With regard to (a) it is concluded that binoculars certainly give their theoretical performance at sky brightnesses from $10^{-2}$ e.f.c. to $10^{-4}$ e.f.c. but that below $10^{-4}$ e.f.c. there is a small falling off in performance. With regard to (b) curves are given showing minimum perceptible contrast as a function of angle of field (from $20^{\circ}$ to $80^{\circ}$) and sky brightness (from $5 \times 10^{-4}$ e.f.c. to $5 \times 10^{-6}$ e.f.c.) The increase of contrast required when the boundary is diffuse is also measured.

36. TESTS OF AVIATION GOGGLE WITH SUN SPOT VISOR

McDonald, Comdr. L. E., United States Naval Air Station, Patuxent River, Maryland, Project No. TED No. PTR - 2576, 8 November 1944, 4 pp. (restricted).

Two series of tests were made with the Aviation Goggle with Sun Spot Visor developed by Lt. Comdr. Peckham and Dr. Miles. In the first series goggle A (transmission of visor-10%, transmission of lens-30%, total transmission-3%) was worn by pilots while looking into the sun. In the second series each subject compared two of five goggles differing in visor and lens transmissions. The subjects were observers on the ground, in the waist of a PBY-5A, and the pilot and co-pilot of a PBY-5A and an SNB. The report concludes: (a) that the Aviation Goggle with Sun Spot Visor is of practical usefulness for ground crews working under conditions of brilliant sun illumination; (b) that it is not practical for use by pilots; (c) that of the goggles tested there is a definite preference for those with minimum total transmission; (d) that the combination of transmission in goggle A would be most suitable for operational use; and (c) that the tests were subjective, and the subjects changed their preference from day to day, from plane to plane, and from ground to air. It is recommended that goggle A and goggle C (transmission of visor-25%, transmission of lens-30%, total transmission-8%) be provided for aviation personnel, exclusive of pilots, whose duties require working in brilliant sun illumination, provided that the goggles are sufficiently ventilated to eliminate fogging and wearer discomfort.

37. FINAL REPORT ON EFFECTIVENESS OF REFLECTION-REDUCING COATING IN REDUCING FLASH FROM AIRCRAFT PLASTIC SURFACES

Cross, Lt. Comdr. H. F., United States Naval Air Station, Patuxent River, Maryland, Report on Project No. TED No. PTR - 2539, 17 November 1944, 6pp. (restricted).

Flash from the plastic enclosure, treated by application of the American Optical Company's two-solution coating #157C-50, was found to have approximately 1/3 of the intensity of the flash from untreated enclosures. Depending on the transmission of the atmosphere at the time, the normal visibility of the flash from the treated surface can be expected to vary from about 2/5 to 2/3 the distance for the untreated enclosure. Application of the special reflection-reducing coating was found to improve pilot visibility through the enclosures generally: (1) by reducing glare and eye strain and (2) by reducing interference with vision caused by reflections and cross-reflections of light or bright objects. This improvement was particularly noticeable on clear sunny days, when flash normally causes greatest difficulty.

## 38. TARGET MODEL DISCS FOR BOMBARDIER TRAINING

Bernreuter, Robert G., Operation Analysis Section, Far East Air Forces, Memorandum Report, 23 September 1944, 9pp. (restricted).

Relief target discs constructed to scale and closely approximating enemy bases and shipping have been built for use with the bombardier trainer for training in identification of pin-point targets and in operation of the bombsight. The target discs are circular, four feet in diameter, less than three and one-half inches in height at the highest point, and are mounted on the target bug of the trainer. The scale is determined by the ratio between the height of the trainer (10 feet) and the simulated altitude of the aircraft; it should yield an area sufficiently large to include major landmarks, yet small enough to include the necessary detail. Advantages of target model discs are: (1) thorough familiarization of student with landmarks and detail of an area to be bombed; (2) stimulation of student interest in practicing aiming.

## 39. EXAMINATION OF ENEMY MATERIEL (OD-113) (AC-77): LUMINESCENCE OF ENEMY AIRCRAFT INSTRUMENT DIALS

DeVore, J. R., NDRC Research Project NRC-32, OEMsr-722, Progress Report No. 111, 16 August 1944, 12pp. (restricted).

Several instruments and dials from captured enemy aircraft were kept in the dark for 24 hours; then the brightness of the radioactive markings was measured with a Macbeth illuminometer fitted with a green filter. The radioactive markings on Japanese instruments are 3 to 4 times as bright as the markings on German instruments. Although the dates of manufacture of the dials are not available, it is believed that this difference is not due to differences in age of the activated phosphors but rather due to an initial difference in intensity of activation. Two of the Japanese dials bore dates showing that they were about two years old. Their brightness values are the same order of magnitude as those of the radioactive markings on standard American dials two years after their manufacture. Consequently, the brightness of the Jap markings when new is probably close to the brightness of similar United States markings. In addition to the instruments and dials, a Japanese "black light" cockpit lamp was compared with American cockpit lamps by placing each, in turn at a fixed distance from a luminescent plaque and measuring the brightness of the plaque with a wide angle photometer. The Japanese cockpit lamp is a much weaker source than either type of American lamp, and it also yields more visible light (principally in the red). However, the radioactive markings on the dials are legible to the dark-adapted eye. Consequently the weak source is sufficiently strong to produce easy legibility.

40. THE INFLUENCE OF BINOCULARS AND TELESCOPES ON THE VISIBILITY OF TARGETS AT TWILIGHT

Hecht, Selig, C. D. Hendley, and Simon Shlaer, Committee on Aviation Medicine, CMR, Report No. 312, 9 June 1944, 6pp. (confidential).

In the use of sighting and observing equipment during operaations in the twilight before sunrise and after sunset, the critical factors which control the range of visibility of a target are (a) the magnifying power and (b) exit pupil diameter of the sighting instrument, and (c) the degree of contrast between target and background. Under twilight conditions magnification is most important, and the more magnification available the greater the range of visibility. With failing light, however, the exit pupil of the sighting instrument becomes increasingly critical, and the larger the pupil the more effective is the sighting instrument for increasing the range of visibility. Because of the reciprocal relation between magnification and exit pupil, for a fixed objective size, there is a critical illumination in the visibility of a given target. Above this critical illumination, increasing the power of the ocular increases the visibility range, even though light is lost through reduction of the exit pupil. Below this critical illumination, increasing the exit pupil, up to a diameter of 7 mm. is more important than magnification. For the low contrast targets studied, this critical illumination is about 0.3 foot-candle. Particularly at the lower illuminations, the contrast between target and background is of prime importance in limiting visibility with sighting equipment. It is recommended that for operations at twilight, sighting instruments should be selected with the highest magnification that can be obtained with a 7 mm. exit pupil. Increasing the diameter of the exit pupil beyond 7 mm. is not profitable. Because contrast between target and background plays a particularly significant role in visibility during twilight, it is recommended that special attention be paid to reducing this factor in personnel and materiel.

41. STUDIES IN VISUAL DISCRIMINATION: RELATION OF MONOCULAR TO BINOCULAR VISION, EFFECT OF ILLUMINATION INTENSITY, DISTANCE, AND OTHER EXTERNAL CONDITIONS ON THRESHOLD

Weymouth, F. W. and M. J. Hirsch, Committee on Aviation Medicine, CMR, Report No. 361, August 1944 (open).

A new distance discrimination test, consisting of a figured plane moving about a vertical axis so that its two ends may be unequally distant from the observer, gave results of about the same reliability as the Howard-Dolman rod apparatus. Reliability of both instruments was increased by the use of a shutter regulating exposure (0.25 sec.). Binocular thresholds depend both on monocular

discrimination of angular size and on retinal disparity. Since the latter cue decreases more rapidly with distance, the importance of the disparity or "binocular" element shows a marked relative decline with distance. Tests over a range of 5 log units of illumination show that the threshold falls in an orderly fashion. The form of the curve is the same as for visual acuity, so that distance discrimination is considered to rest on the same visual capacity. Individual records, while conforming to type, show great variation; that is, the curves may be fitted by the same formula but the three constants vary widely in value and show no correlation with each other. In consequence a person's capacity for distance discrimination at a particular level of illumination cannot be predicted from a test made at a different level.

42. REPORT ON FLIGHT TESTS OF CHANCE VOUGHT FLAT FRONT WINDSHIELD AND BULGED CANOPY INSTALLATION IN MODEL F4U-1D AIRPLANE

United Stated Naval Air Station, Patuxent River, Maryland, Report on Project No. TED No. PTR 1113, 28 November 1944, 4pp. (confidential).

Comments upon visibility astern, vision at acute angles through canopy material, armor protection, cockpit reflection, night visibility, etc.